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THE IMPORTANCE OF QUALITY IN INCANDESCENT LAMPS

INFORMATION OF IMPORTANCE AND INTEREST TO USERS OF INCANDESCENT LAMPS

GENERAL ELECTRIC COMPANY
MAIN LAMP SALES OFFICE, HARRISON, N. J.

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THE IMPORTANCE OF QUALITY IN INCANDESCENT LAMPS.

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We smile at the child's definition of an incandescent lamp —"a hairpin in a bottle," but there are numerous consumers and purchasers of incandescent lamps to whom it is nothing more, who never have understood or appreciated the difference between good and poor lamps, or esteemed the great importance of quality.

One of the greatest drawbacks to successful electric lighting today is inattention to lamp quality, disregard of the proper value of a lamp, its quality, and consideration only of the apparent value—first cost. Poor quality lamps are like barnacles on a ship—they retard the free progress of successful illumination and convert what might be an active and successful business into a slow and uncertain one, unable to do much more than drift at the mercy of the waves of gas and oil competition, and fortunate if indeed it escape utter shipwreck.

The importance of quality in incandescent lamps can hardly be exaggerated. The lamp is the end and aim of the whole lighting system. It is the final translating device which transforms the current into light. Its quality becomes, therefore, like an object at the focus of a microscope, magnified into the greatest importance.

THE LAMP'S SUPREMITY

There is little dispute but that it is the best to use good and efficient machinery in electric lighting stations, that it is wise to have a well proportioned and constructed distributing system. How then can there be any question of what should be an electric lighting axiom? viz., that only incandescent lamps of the highest quality should be used. What folly for a station to install good machinery and well proportioned lines to supply current to poor lamps. It would be as wise for a steamship to have quadruple expansion engines to drive an inefficient propeller.

A good incandescent lamp often overcomes the result of bad machinery or bad management, but poor incandescent lamps will destroy the results and efforts of the best equipped and most capably managed electric lighting installation in the world.

THE BEST LAMP A NECESSITY

There can be honest differences as to whether it is wisest or best to buy the best wire, or this or that cut-out, or a cheap type of socket in preference to a more expensive one, but as regards the lamp there can be but one decision—the best lamp is none too good. This is because the lamp is the chief and final device that produces the light and establishes the quality of the commodity for sale.

There are many who will probably concur in all that has been said to the extent of avoiding the poorest grades of lamps, but who do not consider that minor differences of quality are of any importance, and who actually believe that it is economy to purchase lamps, even if they are inferior to the best, provided they can be bought cheaper.

It is the purpose of this article to point out the error of this, in demonstrating the great importance of quality and how many times more important it is than any saving in first cost.

The quality of a lamp is determined by the average candle-power it furnishes during any given period. As is well known, all lamps decline in candle-power as they are used. It is the relative amount of the decline, other things being equal, which determines the value of a lamp.

WHAT CONSTITUTES QUALITY

An erroneous idea prevails that the quality of the lamp may be determined by the power it consumes when first put on the circuit, i. e., its initial efficiency in watts per candle. The efficiency of a lamp, however, undergoes a gradual change during the time of burning, so that a correct determination of quality necessitates a consideration of the after performance of the lamp, as well as the operation at the start. To properly measure a lamp's value, we must average the results given, taking the average efficiency for a given period of burning, or, since the candle-power determines efficiency, the average candle-power. A reference to the diagram Fig. 1 will make this clear.

Fig. 1 gives the curves of candle-power of two lamps, and the quality of lamp No. 2 is at once seen to be superior to that of lamp No. 1 in the better holding up of the curve of candle-power. Both lamps are of similar voltage and candle-power, and were tested at the same exact initial efficiency (3.1 watts per candle) under the same exact conditions. It is the practice of the best modern stations to take the period in which a lamp loses 20% of its initial candle-power, and from this determine the candle-hours of light given, taking these as the measure of the lamp value. The area included between the candle-power curves above the 80% value and the zero line of candle-power gives the candle-hours.

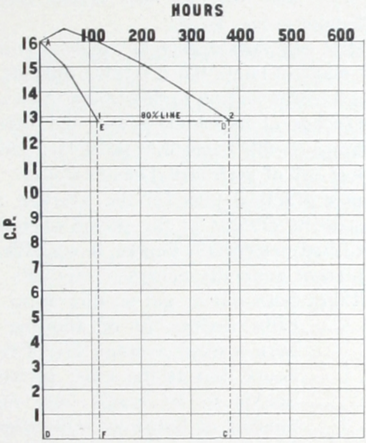

FIG. 1.

For example, in Fig. 1 the area enclosed beneath curve No. 2 is indicated by the letters *a b c d*; that beneath curve No. 1 by *a e f d*. By means of a planimeter these areas are measured, and with proper scale of candle-power and hours, the areas represent the exact number of candle-hours given by the lamps under consideration. The areas of the lamps Nos. 1 and 2, in Fig. 1, have been integrated by a planimeter, and are as follows:

Area of lamp No. 1—*a e f d* equals 1500 candle-hours.
Area of lamp No. 2—*a b c d* equals 6000 candle-hours.

A MEASURE OF QUALITY

Comparison of the two curves, Nos. 1 and 2, shows that lamp No 1, reaches the 80% line in about one-fourth of the time that lamp No. 2 does. To obtain the same amount of light, it would be necessary therefore to renew lamp No. 1 about four times as often as lamp No. 2, which on the basis of first cost of the lamps would make lamp No. 2 four times the value of lamp No. 1, and this we see is the ratio of the respective candle-hour areas.

This method of comparison correctly and fairly determines the value of any make of lamp, but it is quite difficult, if not impossible, for the average station to determine when a lamp has lost a given percentage of its candle-power, and, therefore, difficult to renew lamps on this basis, that is, replace lamps whenever they have lost 20% of their initial candle-power.

A PRACTICAL COMPARISON

If there was a practical plan for the average station to renew all lamps on its circuits at the period when the candle-power had diminished to a certain degree, it would be far preferable to the present generally accepted methods of letting lamps burn until they burn out or get so dim as to be practically useless, or of allowing them to burn a fixed average life of 600 to 1000 hours; but as the most prevalent practice is to let lamps burn for a given number of hours we will adopt a modification of the foregoing method of determination of quality.

We will extend the curves of candle-power to 600 hours and take the area beneath each of these curves in candle-hours as the measure of value. The various makes of American lamps were purchased and tested and classified into four grades. Fig. 2 gives the curves corresponding to each grade.

Taking the areas included between each curve up to the 600 hour line and the zero line of candle-power, we have:

Area of lamp No. 1 to be 8200 candle-hours.
“ “ “ 2 “ 7500 “ “
“ “ “ 3 “ 6500 “ “
“ “ “ 4 “ 5450 “ “

Assuming area of lamp No. 1 as the standard, representing it by 100%, the difference in candle-hours given and the percentage value of the other lamps, is as follows:

Relative Value of Lamps.	Difference in candle-hours of light as compared to best lamp.
No. 1....100%.	No. 1
No. 2.... 91%.	No. 2— 700 candle-hours or 9%.
No. 3.... 80%.	No. 3—1700 candle-hours or 20%.
No. 4.... 66%.	No. 4—2750 candle-hours or 34%.

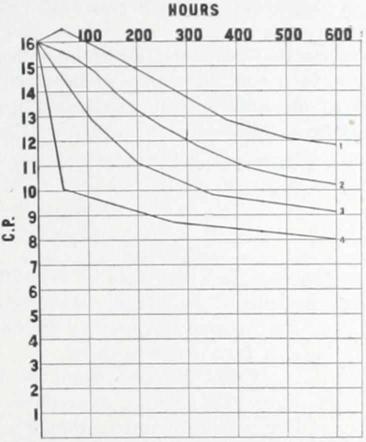

FIG. 2.

VALUE OF THE LIGHT LOST

From these comparative values one might conclude that if lamp No. 1 cost 20 cents, then lamp No. 2 would be worth 91% of 20 cents, or 18.2 cents; lamp No. 3 80% of 20 cents, or 16 cents, and lamp No. 4, 66% of 20 cents, or 13.2 cents. This result, however, only considers the first cost or selling price of the lamp. A proper measure of the difference in quality as compared to the best lamp should consider the cost of the difference in candle-hours, *i. e.*, the value of the light lost. What is the value of this difference in candle-hours or lost light, ranging from 9% or 700 candle-hours in lamp No. 2, to 34%, or 2750 candle-hours in lamp No. 4?

Assuming the station cost of a lamp hour at the low value of ¼ of a cent, the value of 600 hours of the best lamp would be $1.50. On this basis of the value of the light given by the best lamp, the value of the candle-hours difference, or the light lost by using lamps Nos. 2, 3 and 4 is as follows:

Lamp No. 2. Difference or light lost, 700 candle-hours, 9%; value 13.5 cents.

Lamp No. 3. Difference or light lost, 1700 candle-hours, 20%; value 30 cents.

Lamp No. 4. Difference or light lost, 2750 candle-hours, 34%; value 50 cents.

If now we assume that the lowest grade lamp, lamp No. 4, could be purchased for 1 cent, the values of lamps Nos. 3, 2 and 1, when the cost of the difference in candle-hours of light is considered, would be as follows:

Lamp No. 4 assumed as worth....	1	cts.*
" " 3 becomes worth.......	21	"
" " 2 " "	37½	"
" " 1 " "	51	"

This table strikingly shows the value of the difference in quality of incandescent lamps. It is to be noted that this value is estimated upon a very low basis of cost —¼ cent per lamp hour.

A STRIKING DIFFERENCE

From the standpoint of the customer, who pays at least three times the cost assumed above, that is, ¾ cent a lamp hour, lamp No 1 becomes worth $1.50 as compared to 1 cent for lamp No. 4. It is from this, the customer's standpoint, that the matter should be regarded.

Whether it be as a result of supplying poor lamps, or allowing supply houses to sell customers poor lamps, the loss to the consumer is direct and paid for in dollars and cents. The fact that the customer purchases the inferior lamp does not relieve the station from blame or the responsibility of the loss in value of light. The customer can hardly be expected to know or appreciate the value of lamps—it is the station's business to protect him by furnishing or allowing to be sold to him only lamps of the best quality. Otherwise there is dissatisfaction and loss of business, as the customer always blames the station for poor service.

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*Lamp No. 1 is worth 1 cent, plus the value of lost life—50 cents—or 51 cents.

Lamp No. 2 is worth 1 cent, plus the difference in value of lost light between lamp No. 4 and lamp No. 2; that is, 50 cents minus 13½ cents, or 36½ cents, plus 1 cent, giving 37½ cents.

In same the value of lamp No. 3 is estimated.

The answer to those who consider minor differences in quality unimportant is found in comparison of lamps Nos. 1 and 2. Here there is only a difference of 9% in candle-hours of light given, and yet the value of lamp No. 1 (51 cents) is 13½ cents greater than that of lamp No. 2 (37½ cents) estimating light at cost value. Estimating light at what it costs the consumer, the difference in value between the best and the next best lamp is more than 40 cents.

We have assumed a very low figure for lamp No. 4 in taking its value at one cent, in order purposely to emphasize the difference between the best and the poorest lamp. As a fact, the selling price of the poorest lamp made is only a few cents below that of the best.

A PERTINENT QUESTION

Where can be the gain to a central station in saving two or three cents on a lamp and losing 50 cents' worth of light, or, from the customer's standpoint, where is the wisdom in supplying customers with a lamp two or three cents cheaper than the best on the market, and causing him to lose an amount of light which represents $1.50 in value to him?

Were central stations to ask themselves such questions and give more consideration to this subject of quality, there would be fewer stations suffering from Welsbach competition and unprofitable lighting business.

INFORMATION OF IMPORTANCE AND INTEREST TO USERS OF INCANDESCENT LAMPS.

FROM GENERAL ELECTRIC COMPANY'S CATALOGUE NO. 1012.

LIFE AND CANDLE-POWER OF LAMPS.

Since the prime function of an incandescent lamp is to give light, the best lamp is that which gives maximum light at minimum cost. This is an exceedingly simple axiom and yet few users of lamps follow it out in practice. Lamps are repeatedly selected for long life irrespective of good, uniform candle-power. Lamps are often continued in use long after their candle-power has seriously diminished.

An examination of the characteristics of an incandescent lamp will give a clear understanding of the principles applying to their selection and use. A theoretically perfect lamp would maintain its normal candle-power indefinitely, or until the lamp was broken. In practice the deterioration of the lamp filament causes a steady loss of candle-power.

REGARDING LOSS IN CANDLE-POWER

The drop in candle-power is a characteristic of an incandescent lamp always to be borne in mind. The relative drop or loss of candle-power, other things being equal, determines the comparative value of different lamps. We may have a lamp that loses 50% in candle-power inside of 200 hours on a 3.1 watt efficiency basis. This type is almost invariably furnished by the inexperienced manufacturer, and there are many such lamps in the market. Considered from the standpoint of life only, such lamps are excellent, because their filaments deteriorate to such a degree that it is practically impossible to supply enough current to brighten them up to the breaking point, but no discerning station manager would want such dim lamps even with unlimited life. As in the selection of incandescent lamps so in their use—the exclusive consideration of life leads to poor results. Loss of candle-power in a lamp sooner or later makes it uneconomical to continue in use.

There is no lamp yet made which is economical to burn over 1000 hours, and in the great majority of cases the limit is under 600 hours.

An incandescent lamp is nothing more than a transformer, receiving current and transforming it into light. After a certain time this transformer may lose 50% in efficiency, taking practically the same current, but giving only about one-half the light. A boiler or an engine suffering such loss in efficiency would be promptly repaired or replaced. The renewal of incandescent lamps is even more important. The old lamps jeopardize the customer's trade with their poor and expensive light. A customer cares little how efficiently a station is operated, but is much concerned about the quality of light furnished. At the present price of lamps, doubling the number of lamp renewals adds little to cost of operation, while it increases the lighting efficiency 40% to 50%. Some stations attempt to correct the dimness of old lamps by raising the voltage, but this is bad practice, for the increased pressure damages every new lamp placed in circuit. These principles are carefully observed by many of the large lighting companies, and a force of men is employed to weed out and replace all dim lamps. Some such means of keeping the average life below 600 hours should be adopted by every Lighting Company that has any regard for the economical production of light or the satisfaction of their customers.

A simple method is to fix the average life at 600 hours or less and then determine from the station record how many lamps should be renewed each month to keep the average life within this limit. The required number of lamps should be renewed each month.

If, for example, a station decides on an average life not to exceed 600 hours and the station records show that on the average 60,000 lamp hours of current are supplied monthly, then it would be necessary to renew $\frac{60{,}000}{600}$, or 100 lamps a month.

THE IMPORTANCE OF GOOD REGULATION.

SELECTION AND USE OF TRANSFORMERS.

Poor regulation of voltage probably results in more trouble with customers than any other fault in electric lighting service.

Some central station managers act on the theory that so long as the life of the lamp is satisfactory, an increase of voltage, either temporary or permanent, will increase the average light. The fact is that when lamps are burned above their normal rating the average candle-power of all the lamps on the circuit is decreased, and if the station is on a meter basis, it increases the amount of the customers' bills.

Excessive voltage is thus a double error—it decreases the total light of the lamps, and increases the power consumed.

EVILS OF EXCESSIVE VOLTAGE

The loss of light displeases the customers and discredits the service. If light is sold by meter, the increased power consumption dissatisfies the customer; if light is sold by contract, the additional power is a dead loss to the station. If increased light is needed, 20 candle-power lamps should be installed instead of raising the pressure. Their first cost is the same as 16 candle-power lamps; they take but little more current than 16 candle-power lamps operated at high voltage and give greater average light.

Increased pressure also decreases the commercial life of the lamp, and this decrease is at a far more rapid rate than the increase of pressure as shown in the following table. This table shows the decrease in life of standard 3.1 watt lamps due to increase of normal voltage.

Per Cent. of Normal Voltage.	Life Factor.
100	1.000
101	.818
102	.681
103	.562
104	.452
105	.374
106	.310

From this table it is seen that 3% increase of voltage halves the life of a lamp, while 6% increase reduces the life by two-thirds.

Irregular pressure, therefore, necessarily results in the use of lamps in which the power consumption per candle is greater than a well regulated pressure would allow. The result is reduced capacity of station, and reduced station efficiency.

These remarks apply with special force to alternating current stations since we have here two sources of possible irregularity in voltage—the generator and the transformer.

Poor regulation is most apt to occur in the transformers and the utmost care should, therefore, be taken in their selection and use. The efficiency of the average lamp on alternating systems is nearly 4 watts per candle. With good regulation obtained by the intelligent use of modern transformers, the use of lamps of an efficiency of 3.1 watts per candle becomes practicable. It is thus possible to save 25% in power consumption at the lamps and increase the capacity of the station and transformers by the same amount.

THE SAVING RESULTING FROM GOOD REGULATION

In the past two years there has been a marked advance in the method of making transformer installations. The general adoption of higher voltage secondaries gives smaller loss in wires and permits the use of larger transformer units, thus greatly improving the regulation. On this account 50 volt lamps are gradually going out of use. The replacement of a number of small transformers by one large unit, and of old, inefficient transformers by modern types, has also been of immense advantage to stations. A large number of stations, however, still retain these old transformers, and load their circuits with large numbers of small units. Such stations necessarily suffer from loss of power, bad regulation and a generally deteriorated lighting service. Simply as a return on the investment, it would pay all such stations to scrap their old transformers and replace them with large and modern units.

MODERN TRANSFORMER PRACTICE

Proper care in the selection of transformers considers the quality and the size. Quality is the essential consideration and should have preference to first cost. No make of transformer should be permitted on a station's circuit that does not maintain its voltage well within 2% from full load to no load. The simple rule regarding size is to use as large units as possible and thus reduce the number of units as far as the distribution of service permits. Every alternating station should aim to so improve regulation as to permit the satisfactory use of 3 watt lamps.

Good regulation is eminently important to preserve the average life and light of the lamps, to prevent the increase of power consumed by the lamps, and to permit the use of lamps of lower power consumption, so that both the efficiency and capacity of the station may be increased.

Constant voltage at the lamps can be maintained only by constant use of reliable, portable instruments. No switchboard instrument should be relied on, without frequent checking by some reliable standard. Owing to the varying drop at different loads, constant voltage at the station is not what is wanted.

HOW TO MAINTAIN CONSTANT PRESSURE

Pressure readings should be taken at customers' lamps at numerous points, the readings being made at times of maximum, average and minimum load. Not less than five to ten readings should be made at each point visited, the voltmeter being left in circuit for four or five minutes and readings taken every fifteen seconds. The average of all the readings gives the average voltage of the circuits. Lamps should be ordered for this voltage, or if desired, the voltage of the circuits can be reduced or increased to suit the lamps in use. The practical points are to determine the average voltage at frequent periods with a portable voltmeter at various points of the circuits, and then to arrange the voltage of the lamps and circuits so that they agree.

CANDLE-HOURS—THE MEASURE OF LAMP VALUE.

The amount of light given by lamps of the same efficiency is the only proper measure of their value. The amount of light given, expressed in candle-hours, is the product of the average candle-power for a given period by the length of the period in hours.

Many of the best central station managers consider that a lamp has passed its *useful life* when it has lost 20% of its initial candle-power. In the case of a 16 candle-power lamp the limit would be 12.8 candle-power. The period of time a lamp burns until it loses 20% of its candle-power may therefore be accepted as its useful life. The product of this period in hours by the average candle-power gives the "candle-hours" of light for any given lamp.

The better a lamp maintains its candle-power under equal conditions of comparison the greater will be the period of "useful life" and therefore, the greater will be the "candle-hours." This measure is, therefore, the only proper one with which to compare lamps and determine their quality.

The practical method of comparison is as follows:—Lamps of similar candle-power and voltage are burned at the same initial efficiency of 3.1 watts per candle on circuits whose voltage is maintained exactly normal. At periods of 50, 75, or 100 hours the lamps are removed from the circuits and candle-power readings taken, the lamps being replaced in circuit at the end of each reading. Readings are thus continued until the candle-power drops to 80% of normal. The results obtained are then plotted in curves, and the areas under these curves give the "candle-hours" and the relative value of the different lamps.

VARIATION IN CANDLE-POWER AND EFFICIENCY.

In the following table is shown the variation in candle-power and efficiency of standard 3.1 watt lamps, due to variation of normal voltage.

Per Cent. of Normal Voltage.	Per Cent. of Normal Candle-power.	Efficiency in Watts Per Candle.
90	53	4.68
91	57	4.46
92	61	4.26
93	65	4.1
94	69½	3.92
95	74	3.76
96	79	3.6
97	84	3.45
98	89	3.34
99	94½	3.22
100	100	3.1
101	106	2.99
102	112	2.9
103	118	2.8
104	124½	2.7
105	131½	2.62
106	138½	2.54

Example.—Lamps of 16 candle-power, 105 volts, and 3.1 watts, if burned at 98% of normal voltage, or 103 volts, will give 89% of 16 candle-power, or 14¼ candle-power, and the efficiency will be 3.34 watts per candle.

LAMP RENEWALS.

The necessity for frequent lamp renewals is urgent on all systems regardless of the cost of power and whether lamp renewals are charged for or furnished free.

No matter how well constructed or operated, an electric lighting plant may be, it cannot furnish clear, good light unless the circuits be periodically swept clean of the dim lamps.

This cleaning out of dim lamps cannot be left to the customer. To be thorough and effective, lamp renewals must be made by the lighting company and without charge. Only by free renewals can a station have that complete control of its lighting service, which is requisite to perfect results. The present price of lamps is so low as to make it possible for all stations to furnish free renewals at but slight expense. Free renewals could be profitably adopted by all stations instead of a reduction of rates.

With free renewals, one of the following methods should be adopted:

1. Periodically remove all lamps from the circuits one to four times per year, according to conditions, and replace them by new ones. Photometer the lamps removed and save those measuring above a prescribed limit (say 13 c.p.) for use at high voltage points, or locations where reduced candle-power is of slight importance. Scrap the remaining lamps.

2. Give a new lamp in *exchange* for an *old* one for, say, every $3.00 worth of current supplied, or for any fixed amount determined by the meter rates and conditions.

The second plan is an excellent one, in that it offers a bonus for the use of current and regulates renewals on the correct basis of number of hours of lamp service. It can be profitably adopted wherever meters are in use. A station attendant should visit customers quarterly and install the number of new lamps due each, removing and returning to the station an equal number of old lamps. If station attendance is limited, the lighting company can fill out and mail to their customers, each quarter year, blanks similar to the following:

Office of
ELECTRIC LIGHT COMPANY.

.... 189

Due to Mr...

..............16 candle-power lamps, on the return of an equal number of dim lamps, for the quarter year ending............. which is on the basis of one lamp for every $3.00 of current supplied.

Present this Slip at the Station, or Office.

....

In cases where lamps must be charged for, some measures should be adopted to induce customers to renew their dim lamps; as, otherwise, dim lamps will be continued in service as long as they will burn.

A good method is to offer new lamps in exchange for dim ones (not burned out) at a reduction in price of one-quarter or one-half cost. A customer, for example would save by paying, say, half price for the renewal of a dim lamp, instead of waiting and paying full price when the lamp burns out.

Another method is to offer lamps for renewals at less than cost, say 15 cents each, and reserve the right to say when lamps shall be renewed. Such a plan works well, as no customer can justly complain when the company renews lamps at less than cost.

The price of lamps to the customer in any case should be made as low as possible—cost price or below cost—for the reason that profit on the sale of lamps is secondary in importance to the sale of current and improvement in quality of lighting service. High charges and illiberal methods in sale or supply of lamps invariably deteriorate the lighting service, for the following reasons:

1. Customers are induced to purchase cheap lamps from outside parties, and, therefore use a low grade of lamps.

2. Customers tend to retain lamps in service as long

as they will last, and thus load up the circuits with numbers of old and dim lamps.

Every station should have some system of lamp renewals, which will not depend upon the customer, and which will limit the average life of the lamps to within 600 hours.

POINTS TO BE REMEMBERED.

That a constant pressure at the lamps must be maintained.

That the lamps are not to be used to the point of breakage —they should be renewed when they become dim.

That satisfaction to customers, and the success of electric lighting is dependent upon good, full and clear light, which old, black and dim lamps cannot give.

That to furnish a good, full and clear light is as much a part of the Lighting Company's business as to supply current to light the lamps.

That a company should always endeavor to keep the average life of lamps within 600 hours.

That to renew dim lamps properly on the free renewal system, inspectors should examine the circuits regularly when the lamps are burning. If lamp renewals are charged to customers, induce them to exchange their dim lamps.

FAULTS IN INCANDESCENT LAMPS.

RAPID LOSS OF CANDLE-POWER.

Rapid loss of candle-power is one defect in incandescent lamps, and we have shown that all lamps suffer a gradual loss of candle-power as they are used. A very rapid loss in candle-power is, however, a real fault, due to inexperienced manufacture, or use at excessive voltage. The remedy is to purchase only lamps of standard reputation produced by the experienced manufacturer and to maintain the pressure at normal on the lamps. The pressure should be carefully tested with accurate portable instruments at the lamp sockets, and if found high, the pressure should be regulated to accord with the voltage of lamps, or lamps supplied to accord with the pressure.

BLACKENING OF BULBS.

Another defect in incandescent lamps is the blackening of bulbs, although this is more often a supposed defect than a real one. A lamp may lose in candle-power and show but little blackening, and on the other hand, a lamp may get quite black and lose little in candle-power. Thus a 50-volt lamp which has a more stable filament than the 110-volt lamp, often shows considerable blackening with little loss of candle-power.

Blackening in good lamps results from either high pressure or excessive life. This is a supposed fault. The best of lamps, if burned too long, will always show a certain amount of blackening. The remedies are, of course, regulation of pressure and frequent renewals.

The above are the most important defects to be found in incandescent lamps.

GENERAL ILLUMINATION.

The subject of illumination has been divided by Mr. E. L. Elliott, to whom we are indebted for many suggestions, into the following sub-divisions: Intensity or Brilliancy, Distribution, Diffusion and Quality.

INTENSITY OR BRILLIANCY.

The average brilliancy of illumination required will depend on the use to which the light is put. "A dim light that would be very satisfactory for a church would be wholly inadequate for a library and equally unsuitable for a ballroom."

The illumination given by one candle at a distance of one foot is called the "candle-foot" and is taken as a unit of intensity. In general, intensity of illumination should nowhere be less than one candle-foot, and the demand for light at the present time quite frequently raises the brilliancy to double this amount. As the intensity of light varies inversely with the square of the distance, a 16 candle-power lamp gives a candle-foot of light at a distance of four feet. A candle-foot of light is a good intensity for reading purposes.

Assuming the 16 candle-power lamp as the standard, it is generally found that two 16 candle-power lamps per 100 square feet of floor space give good illumination, three very bright, and four brilliant. These general figures will be modified by the height of ceiling, color of walls and ceiling and other local conditions. The lighting effect is reduced, of course, by an increased height of ceiling. A room with dark walls requires nearly three times as many lights for the same illumination as a room with walls painted white. With the amount of intense light available in arc and incandescent lighting, there is danger of exceeding "the limits of effective illumination and producing a glaring intensity," which should be avoided as carefully as too little intensity of illumination.

DISTRIBUTION OF LIGHT.

Distribution considers the arrangement of the various sources of light and the determination of their candle-power. The object should be to "secure a uniform brilliancy on a certain plane, or within a given space. A room uniformly lighted, even though comparatively dim, gives an effect of much better illumination than where there is great brilliancy at some points and comparative darkness at others. The darker parts, even though actually light enough, appear dark by contrast, while the lighter parts are dazzling. For this reason naked lights of any kind are to be avoided, since they must appear as dazzling points, in contrast with the general illumination."

The arrangement of the lamps is dependent very largely upon existing conditions. In factories and shops, lamps should be placed over each machine or bench so as to give the necessary light for each workman. In the lighting of halls, public buildings and large rooms, excellent effects are obtained by dividing the ceiling into squares and placing a lamp in the center of each square. The size of square depends on the height of ceiling and the intensity of illumination desired. Another excellent method consists in placing the lamps in a border along the walls near the ceiling.

For the illumination of show windows and display effects, care must be taken to illuminate by reflected light. The lamps should be so placed as to throw their rays upon the display without casting any direct rays on the observer.

The relative value of high candle-power lamps in case of an equivalent number of 16 candle-power lamps is worthy of notice. Large lamps can be efficiently used for lighting large areas, but in general, a given area will be much less effectively lighted by high candle-power lamps than by an equivalent number of 16 candle-power lamps. For example, sixteen 64 candle-power lamps distributed over a large area will not give as good general illumination as sixty-four 16 candle-power lamps distributed over the same area. High candle-power lamps are chiefly useful when a brilliant light is needed at one point, or where space is limited and an increase in illuminating effect is desired.

DIFFUSION OF LIGHT.

"Diffusion refers to the number of rays that cross each point. The amount of diffusion is shown by the character of the shadow. Daylight on a cloudy day may be considered perfectly diffused; it produces no shadows whatever. The light from the electric arc is least diffused, since it emanates from a very small surface; the shadows cast by it have almost perfectly sharp outlines. It is largely due to its high state of diffusion that daylight, though vastly more intense than any artificial illumination, is the easiest of all lights on the eyes. It is a common and serious mistake, in case of weak or over-strained eyes to reduce the intensity of the light, instead of increasing the diffusion."

QUALITY OF LIGHT.

"Aside from difference in intensity, light produces many different effects upon the optic nerves and their centers in the brain. These different impressions we ascribe to difference in the quality of the light. Thus, 'hard light,' 'cold light,' 'mellow light,' 'ambient light,' etc., designate various qualities. Quality in light is exactly analogous to timbre or quality in sound, which is likewise independent of intensity. The most obvious differences in quality are plainly those called color. But color is by no means the element of quality. The proportion of invisible rays and the state of diffusion, are highly important factors, but on account of not being directly visible, they have been generally overlooked, and are but imperfectly understood."

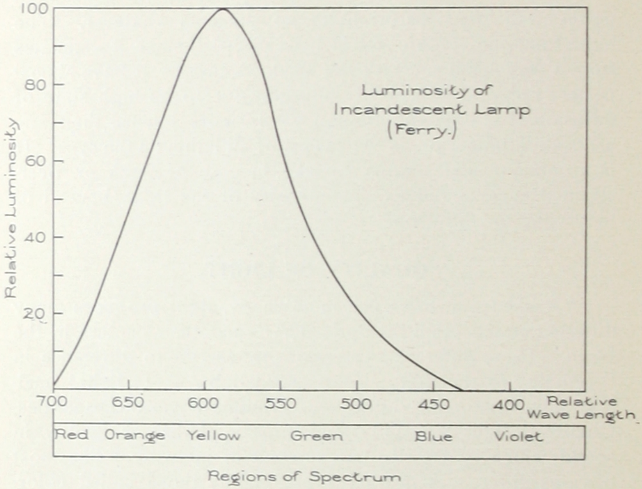
LUMINOSITY OF INCANDESCENT LAMPS.

As showing the quality of the incandescent light, we present here a curve showing the relative luminosity of an incandescent lamp at different regions of the visible spectrum.

On this subject Mr. E. L. Nichols states the following:

"The most important wave lengths, so far as light-giving power is concerned, are those which form the yellow of the spectrum and the relative luminosity falls off rapidly both toward the red and the violet. The longer waves have, however, much more influence upon the candle-power than the more refrangible rays.

"Luminosity is the factor which we must take into account in seeking a complete expression for the efficiency of any source of illumination, and the method to be pursued in the determination of luminosity must depend upon the use to which the light is applied. If we estimate light by its power of bringing out the colors of natural objects, the value which we place upon the blue and violet rays must be very different from that which would be ascribed to them, if we consider merely their power of illumination as applied to black and white. In a picture gallery, for instance, or upon the stage, the value of an illuminant increases with the temperature of the incandescent material out of all proportion to the candle-power, whereas, candle-power affords an excellent measure of the light to be used in a reading room."



RELATIVE VALUE OF ARC AND INCANDESCENT LIGHTING.

The relative value of the arc and incandescent systems of lighting is frequently difficult to determine. Incandescent lamps have the advantage that they can be distributed so as to avoid the shadows necessarily cast by one single source of light. Arc lamps used indoors with ground or opal globes cutting off half the light, have an efficiency not greater than two or three times that of an incandescent lamp. Nine 50 watt, 16 candle-power lamps consume the same power as one full 450 watt arc lamp. It has been found that unless an area is so large as to require 200 to 300 incandescent lights distributed over it, arc lamps requiring equal total power will not light the area with as uniform brilliancy.

THE CORRECT USE OF LIGHT.

HOW TO AVOID HARMFUL EFFECTS ON THE EYES.

An objection frequently urged against the incandescent lamp is that it is harmful to the eyes and ruins the sight. This is true only in so far as the lamp may be improperly used. Any form of light as frequently misused would produce the same harmful results. Few people think of attempting to read by an unshaded oil lamp, and yet many will sit in the glare of a clear glass incandescent lamp. Incandescent lamps are more generally complained of because, unlike oil or gas, they can be used in any position. Bookkeepers and clerks are often seen with an incandescent lamp at the end of a drop hanging directly in front of their eyes—an impossible position of the light from gas or oil.

The first hygienic consideration in artificial lighting is to avoid the use of a single bright light in a poorly illuminated room. In working under such a light, the eye is adapted to the surrounding darkness and yet there is one spot in the middle of the eye that is kept constantly fixed on the very bright light. The brilliancy of the single light acting on the eye adjusted to darkness works harm. There should be a general illumination of the room in addition to any necessary local light. If sufficient general illumination is provided, the eye is adjusted to the light, and the local light can be safely used. The ideal arrangement provides general illumination so strong that a pencil placed on the page of a book casts two shadows of nearly equal intensity—one coming from the general light and the other from the local light.

Care should also be taken to prevent direct rays from striking the eye. The light that reaches the eye by day is always reflected. In reading or writing, to avoid shadows, the light should come over the left shoulder. Only the reflected rays can then reach the eye.

Another point to be avoided is the careless general use of clear glass, unshaded lamps. Frosted bulbs should be used in place of clear glass where soft light for reading is required. The intensity of light reflected from a small source is increased, and intense light injures the eyes. With a clear glass globe the whole volume of light proceeds directly from the small surface of the lamp filament. With a frosted bulb the light is radiated from the whole surface of the bulb and while the total illuminating effect is practically undiminished, the light is softened by diffusion to the great comfort and relief of the eyes.

Finally, the use of old, dim and blackened lamps giving but a small fraction of their proper light is very often a source of trouble in not supplying a sufficient quantity of light. Users of lamps are not often aware of the loss in candle-power a lamp undergoes and so it happens that lamps are retained in use long after their efficient light giving power has vanished. Proper attention to lamp renewals on the part of the central stations is necessary to correct this evil.

The correct use of light requires:

That there should be general illumination in addition to the light near at hand.

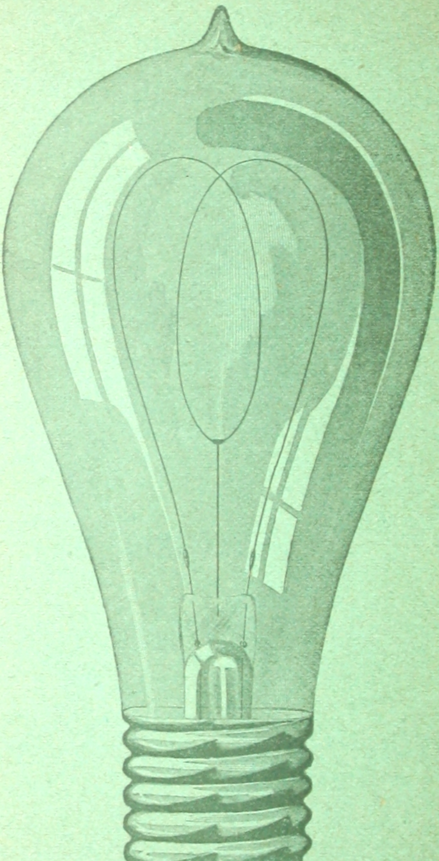
That only reflected light should reach the eye. The light should be so placed as to throw the direct rays on the book or work and not in the eye.

That the light should be placed so that the shadows will not fall on the work in hand.

That shades and frosted bulbs should be used to soften the light.

That lamps be frequently renewed to keep the light up to full candle-power.

THE NEW TYPE EDISON LAMP



STANDARD OF THE WORLD